Improving The Sea Surface Wind Retrieval Algorithm For NASA Scatterometers Using Atmospheric Boundary Layer Models

Young-Joon KIM, Kyung S. PAK, Carol S. HSU, Philip S. CALLAHAN
R. Scott DUNBAR, S. Vincent HSIAO, Anzhen ZHANG

Jet Propulsion Laboratory, Mail Stop 300-319
California Institute of Technology
4800 Oak Grove Dr., Pasadena CA 91109, USA
TEL 818-354-8354, FAX 818-393-5184
young-joon.kim@jpl.nasa.gov

ABSTRACT

The use of an atmospheric boundary layer (ABL) model is investigated to improve wind retrieval algorithms for NASA scatterometer projects. The ambiguity in wind direction retrieved from scatterometer measurements is removed with the aid of physical directional information obtained from the ABL model.

This approach is based on the observation that sea level pressure is scalar and its field is more coherent than the corresponding wind field, and also that the measurement errors of sea level pressure are small compared with those of the retrieved wind vectors.

A wind field obtained from the scatterometer measurements is first used to derive a pressure field by using an ABL model. After properly filtering small-scale noise in the derived pressure field, the wind field is retrieved by using an inverted ABL model. This derived wind information is then used to remove wind vector ambiguities.

It is found that the ambiguity removal skill can be improved when the new scheme is used properly in conjunction with the median filter adopted for the scatterometer wind dealiasing. Moreover, it is believed that the new methodology will mitigate the dependency of the wind processing algorithm on external inputs, i.e., products of numerical weather prediction systems, which reveal deficiencies in accurately resolving some smaller scale and/or sporadic atmospheric phenomena.

INTRODUCTION

Sea surface winds obtained by scatterometers on board satellites have been a major data source to help advance the studies of many atmospheric and/or oceanic phenomena, such as El Niño. The past, present and future missions of the NASA Scatterometers, i.e., SEASAT, NSCAT, QuikSCAT and SeaWinds, respectively, are playing a major role in those studies.

The current ground data processing algorithm for NASA Scatterometers is based on techniques to retrieve ocean vector winds from microwave backscattering coefficients for ocean surface waves utilizing a geophysical model function and a maximum likelihood estimation (systematically compared in [1]), as is briefly summarized in [2]. Since the first stage of the processing yields multiple wind vector solutions differing widely in its directions, i.e., ambiguities, a median filter is used to choose a vector consistent with wind vector field, as was discussed in [3].

The current algorithm, however, also utilizes wind directional information from numerical weather prediction (NWP) models to initialize the median filter algorithm [4]. This method is very effective, but raises some concerns regarding its performance. First, this so-called NWP nudging inevitably relies on external input, i.e., the NWP product. Without good NWP data available in time, the performance of the processing may degrade considerably by having to rely only on the median filter initialized by the vectors from highest-likelihood wind retrieval. Second, the accuracy of the selected wind field may be overly dependent on that of an NWP model, which is an undesirable result. For example, if the NWP model fails to accurately simulate a hurricane for its magnitude and/or location, more accurate measurements by a scatterometer may erroneously be altered by the NWP nudging scheme. This can be serious because the prediction skills of contemporary NWP models are not very good for such an atmospheric phenomenon as hurricane.

As an effort to alleviate these problems, a new approach to ambiguity removal which uses physically-based models is proposed based on the methodology given in the next section.

METHODOLOGY

The methodology is based on the knowledge that sea-level pressure field is more coherent over large scales than a surface wind vector field and thus complements the wind field in describing smaller-scale systems as discussed in [5]. This means that unlike the noise in wind field, those in corresponding pressure field can be reduced by spatially smoothing the pressure field or by performing more general noise filtering if available.

Figure 1 shows this approach as a flow chart. A first-guess field is obtained from the retrieved scatterometer wind vectors selected by the median filter initialized with the highest-likelihood wind vectors. This field is then used to derive a pressure field by using an atmospheric boundary layer (ABL) model. Next, after smoothing the pressure field to filter out small-scale noise, a wind field is re-derived by using an inverted ABL model. This improved wind information is then used to initialize the scatterometer ambiguity removal process.

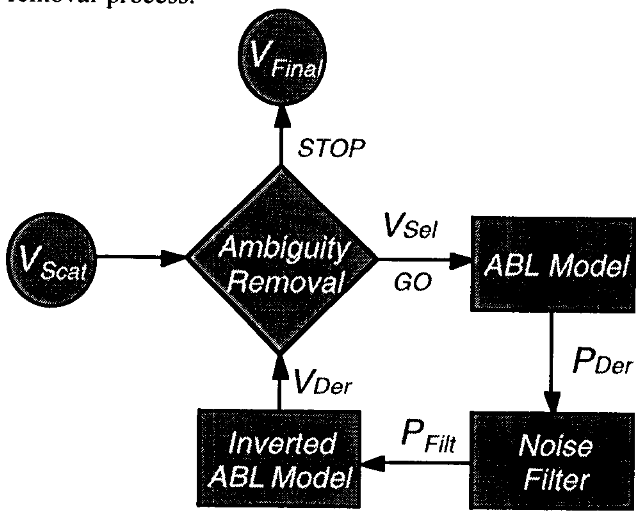

Fig.1. Flow diagram for the ABL-assisted ambiguity removal algorithm.

INPUT DATA AND MODELS USED

The SeaWinds simulation code has been used to generate the scatterometer wind vectors from an NWP model product (NCEP 2.5° resolution). The NWP wind is thus regarded as the "true wind" that is the basis for calculating the "skill". The data correspond to 5 May 1995 for a domain in south-east Asia in northern hemisphere mid-latitudes (115E ~ 135E; 7N ~ 30N). The ABL model used is that of Brown and Liu [6]. For simplicity, an Ekman layer model of Yu [7] has been used as an alternative to the inverted version of the ABL model. We coupled the ABL model and the Ekman layer model to use as a stand-alone scheme for performing the ambiguity removal.

As a consistency check, the scheme was tested against the NWP wind data to see if the wind vector is reproduced from the pressure field which is originally obtained from the NWP wind input. The check was in general successful after some adjustments of some Ekman layer model parameters.

TEST RESULTS

For clarity, a subdomain of the original domain is displayed. Figure 2 shows the pressure field derived by the ABL model from the median-filter selected scatterometer winds. Figure 3 shows the winds derived by the Ekman layer model from the smoothed pressure field. Figure 4 shows the NWP winds and corresponding pressure derived by the ABL model. These NWP winds were used to simulate the scatterometer winds shown in Fig. 2.

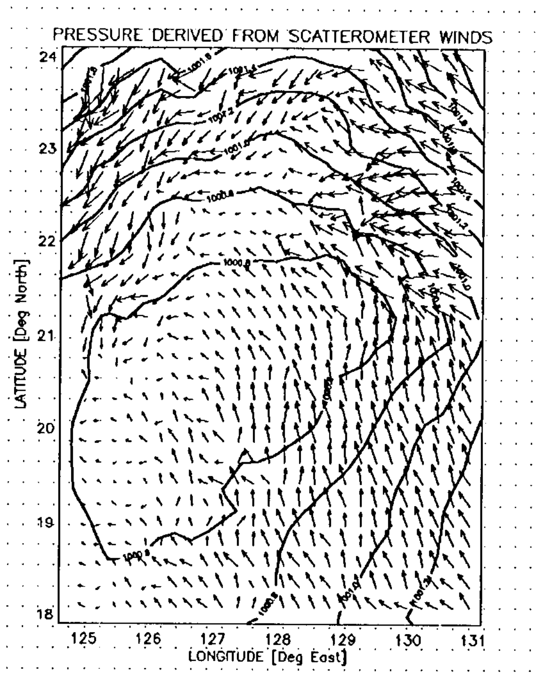

Fig.2. Scatterometer winds (arrows) derived by the SeaWinds simulation algorithm and pressure field (contours) calculated from the ABL model using the winds as input.

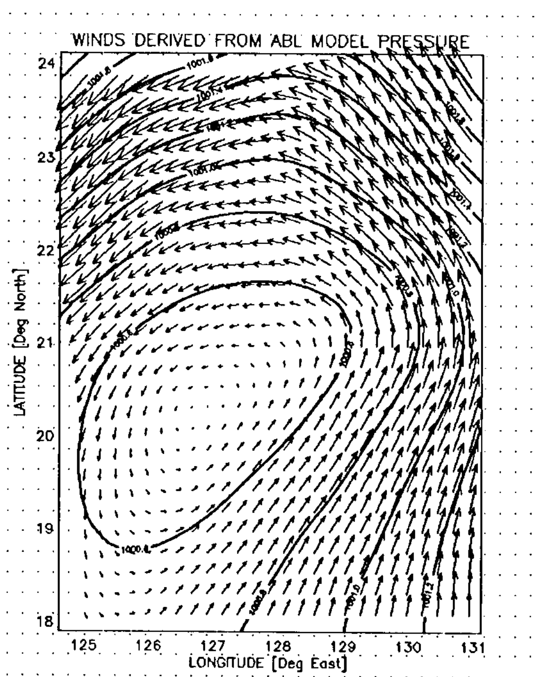

Fig.3. Smoothed version of the pressure field (contours) calculated from the ABL model shown in Fig. 2 and winds (arrows) calculated from the Ekman layer model using the pressure as input.

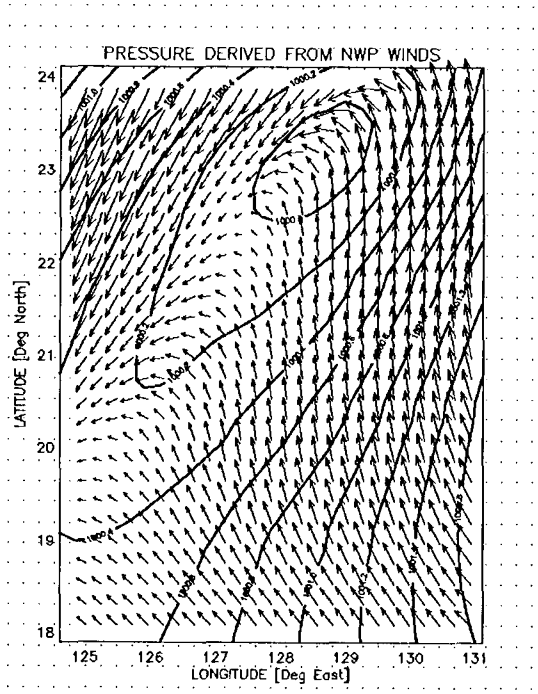

Fig.4. Winds (arrows) obtained from a numerical weather prediction model and pressure field (contours) calculated from the ABL model using the winds as input.

DISCUSSION AND FURTHER REMARKS

The winds derived from the Ekman layer model (generally speaking, from an ABL model) shown in Fig. 3 are used for nudging the original scatterometer winds, i.e., initializing the median filter. We assume that the smoothing of the pressure field filters only the noise part of small-scale features. However, we found that the vectors in the weak wind region of Figs. 2 and 4 are quite different from those in Fig. 3. This is a result of the smoothing. Despite this, it was found that the skill for the subdomain has been improved by about 10%. This may be interpreted to mean that the smoothing of the pressure field filters at least some of the unphysical part of the noise. We found that the skill usually degrades when complex mesoscale features are present, based on our other case studies.

The use of NWP product for nudging is based on the argument that its skill is reasonably good, which may not be the case with small-scale features. While processing actual scatterometer measurements from satellites, it may be possible that useful information can be erroneously discarded by the NWP nudging.

Through a series of case studies, we found that the performance of the scheme tends to degrade near the edges of the ABL model domain where the median filter sometimes totally reverses the wind vectors. This is because the performance of the scheme depends largely on the quality of the input to the ABL model, i.e., on the performance of the median filter. A technique of extending the ABL domain to alleviate this problem is currently being investigated.

We acknowledge that the current scheme should be improved by using the actual inverted version of the ABL model rather than using the overly simple Ekman layer model (for the example shown in this paper, the drag coefficient was set to zero in deriving the wind vectors from the pressure field). This could improve the performance of the scheme. In addition, this study used simulated scatterometer data obtained from NWP model winds. The scheme needs to be tested against real satellite measured scatterometer data.

Finally, it should be noted that the skill calculated in this study is for simulated scatterometer data with respect to NWP product. For a more robust validation of the scheme, actual wind observations, such as those from buoys, will have to be used.

ACKNOWLEDGMENTS

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